Vortex pinning study on epitaxial $YBa_2Cu_3O_{7-x}$ thin film grown on decorated MgO(001) single crystal substrates with $La_{0.66}Sr_{0.33}MnO_3$ nano-islands

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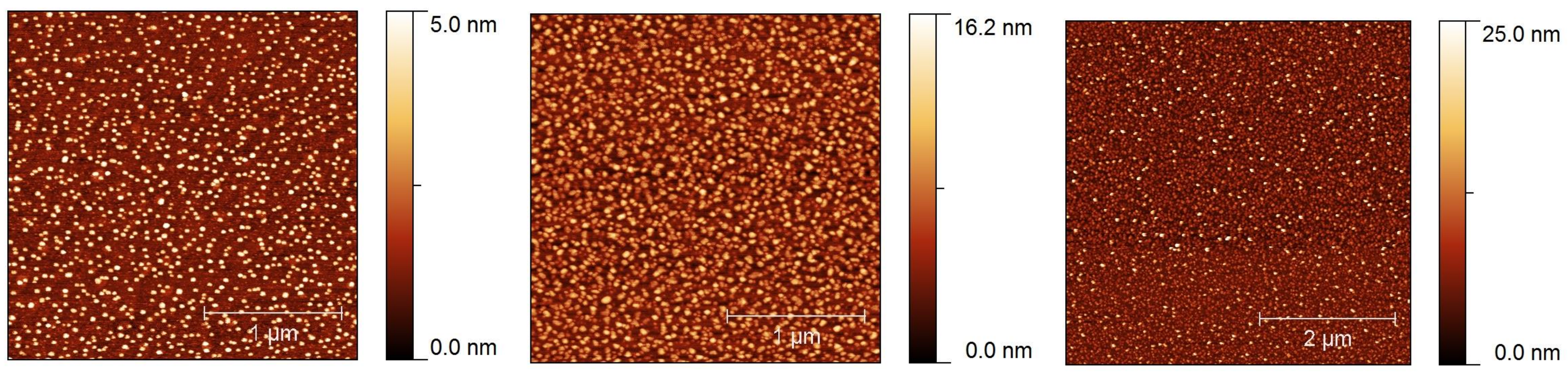
Abstract In the present paper we investigate the influence of $La_{0.66}Sr_{0.33}MnO_3$ (LSMO) nanostructures on the transport and magnetic properties of $YBa_2Cu_3O_7$ (YBCO) thin films. The LSMO nanostructures were obtained by polymer assisted deposition (PAD). The polymer assisted deposition technique is a promising alternative for the deposition of buffer layers for high temperature superconducting thin films, in coated conductor applications. By choosing the appropriate deposition conditions nano-islands having a mean diameter of 20 nm were grown on MgO (001) single crystal substrates, with a highly uniform substrate coverage. Their density was 500 μm^{-2}. No short length ordering of the particles was observed. The as-obtained surface decorated substrates were used as templates for the subsequent growth of YBCO films. The superconducting layers were grown by co-evaporation. The aim of the study is to characterize the pinning landscape produced by the nanostructures. An increased critical current density and pinning force was recorded for the YBCO film deposited on the as-decorated substrates in all measured field and temperature ranges. However, a detailed analysis of the pinning force density, close to the critical transition temperature, revealed that a single pinning mechanism is present in both the single YBCO film and the one deposited on the LSMO decorated substrate. Taking into account the TEM and XRD analyses, we ascribe the enhanced superconducting properties to the structural defects induced in the YBCO film by the LSMO nano-islands. No magnetic pinning contribution was observed, as expected due to the ferromagnetic nature of LSMO.

Morphological properties of LSMO nanoparticles obtained by PAD

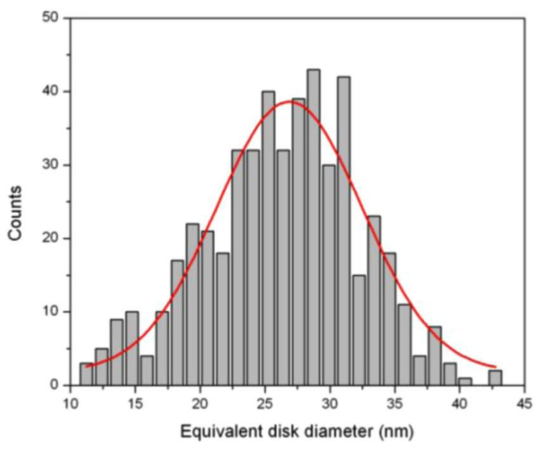
- Polymer Assisted Deposition (PAD) of $La_{0.66}Sr_{0.33}MnO_3$ (LSMO) nanostructures on MgO (001) single crystal substrates

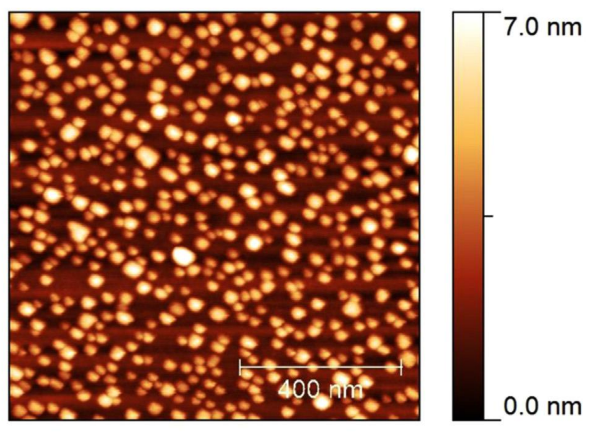


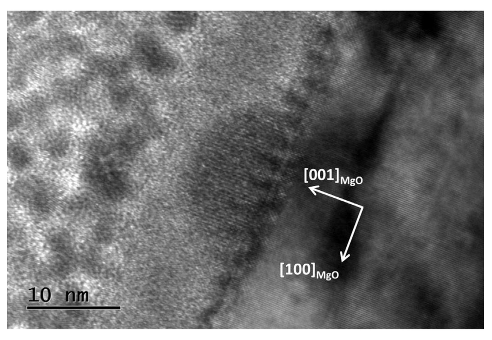
Solution concentration (nanoparticle density):

C= 0.001 M (200 μm^{-2}) C= 0.007 M (~500 μm^{-2}) C= 0.01 M (~500 μm^{-2})

- Nanostructure densities appear to saturate above C = 0.005 M to approximately 500 μm^{-2};

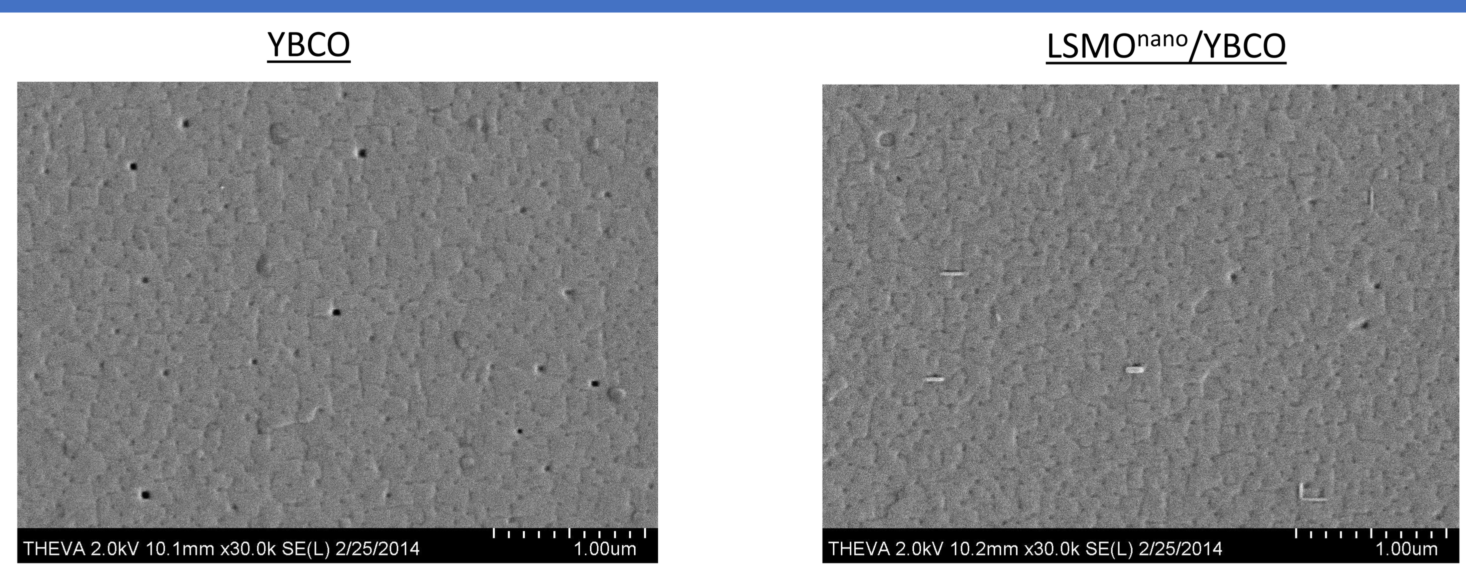




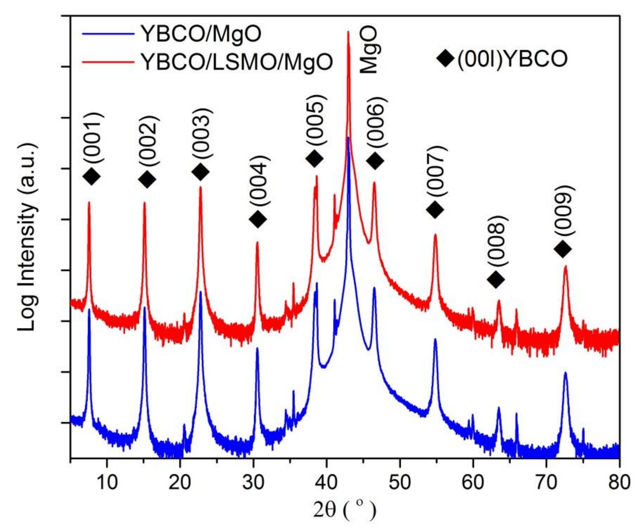


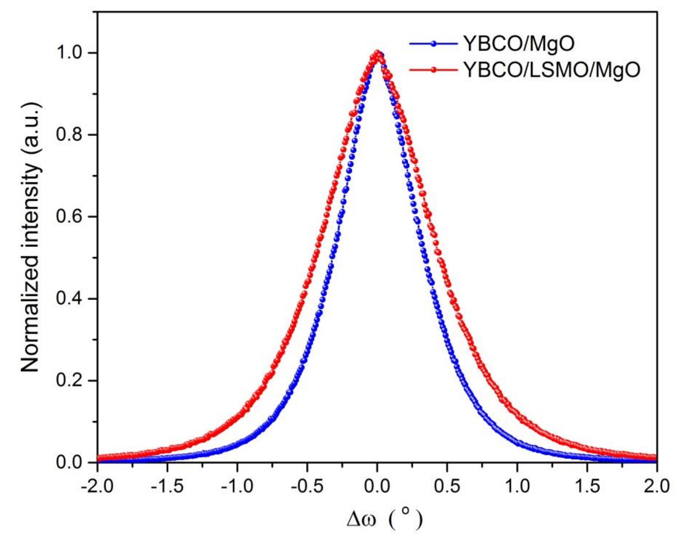
- Mean LSMO dot diameter was found to be 27 ±11 nm
- Average nano-dot height is approx. 6nm
- Nanodots were epitaxially grown on the MgO susbtrates with the epitaxial relationship: (001)LSMO||(001)MgO, and [100]LSMO||[100]MgO

Morphological and structural properties of YBCO and $LSMO^{nano}$/YBCO thin films



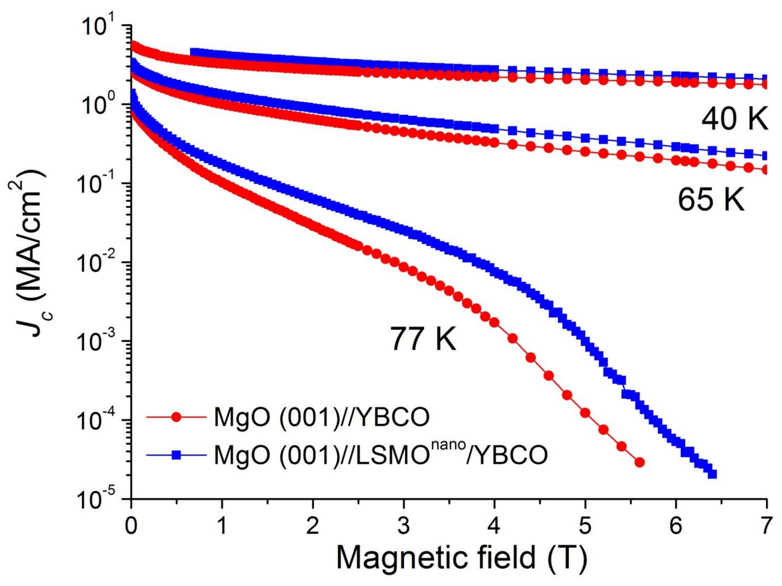
- YBCO 100 nm thick films were deposited by co-evaporation technique (ceraco GmbH)
- good homogeneity, very low rms roughness, 2-3 nm (evaluated by AFM)
- smaller grain size in the case of the YBCO film grown on decorated substrates

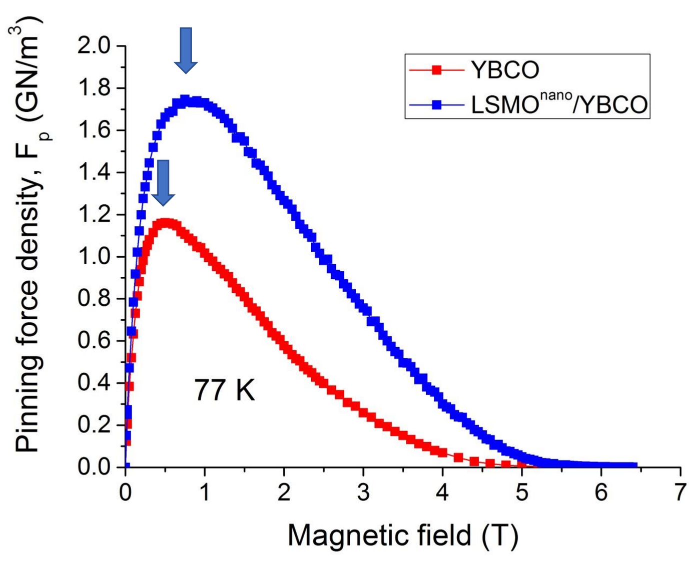




- both films exhibit an epitaxial growth;
- higher FWHM of the YBCO layer deposited on the LSMO nano-dots;

Superconducting transport properties of YBCO and $LSMO^{nano}$/YBCO thin films



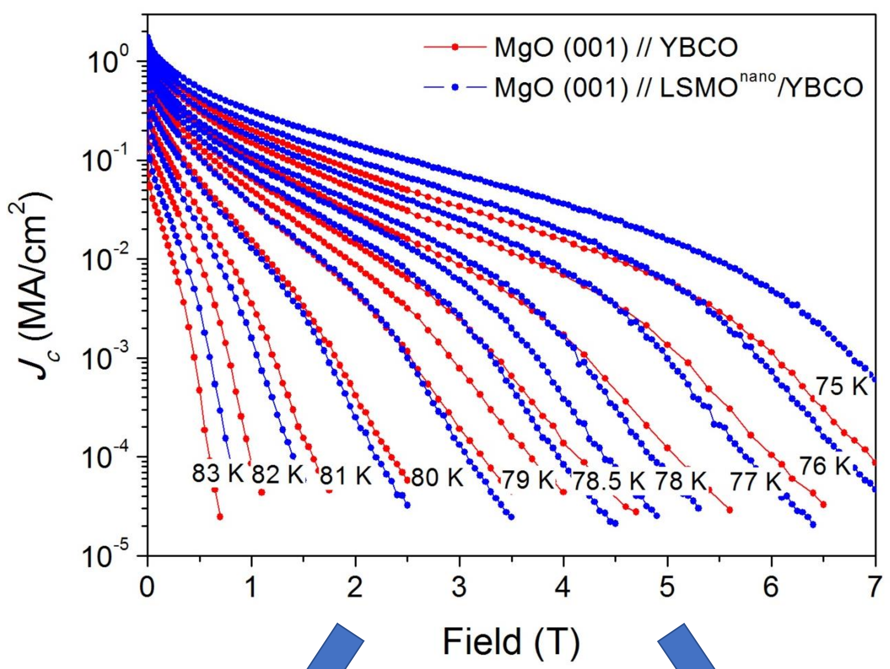


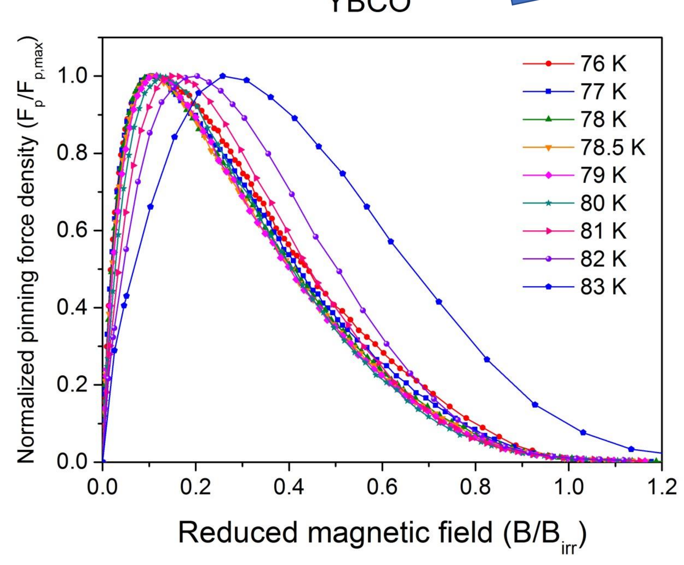
Sample	Tc (K)	Jc (MA/cm^2) @ 77 K, 0 T
YBCO	83.9	1.1
$LSMO^{nano}$/YBCO	84.1	1.4

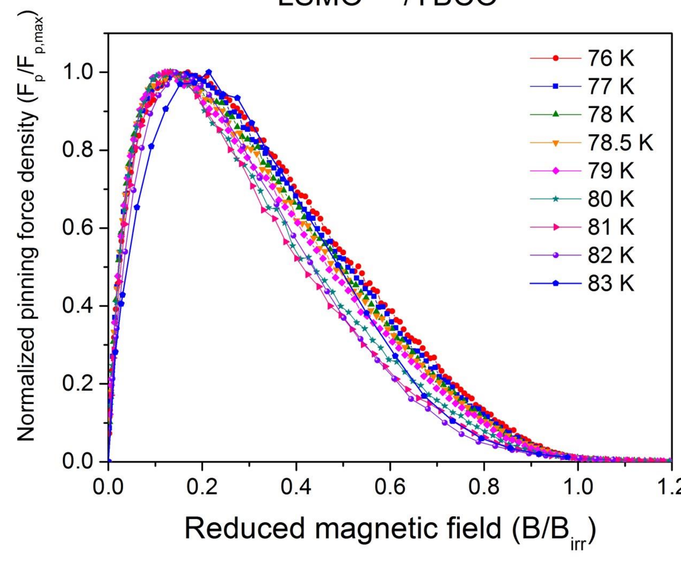
- Matching field, B_m: YBCO – **0.6 T**
  $LSMO^{nano}$ /YBCO – **1 T**
- Pinning site density: YBCO ~ **300 μm^{-2}**
  $LSMO^{nano}$ /YBCO ~ **500 μm^{-2}**
  (good agreement with LSMO dot density)

- Superior current carrying capabilities were demonstrated in the case of the $LSMO^{nano}$/YBCO film over the whole magnetic field range at different temperatures

Pinning population investigation in YBCO and $LSMO^{nano}$/YBCO thin films

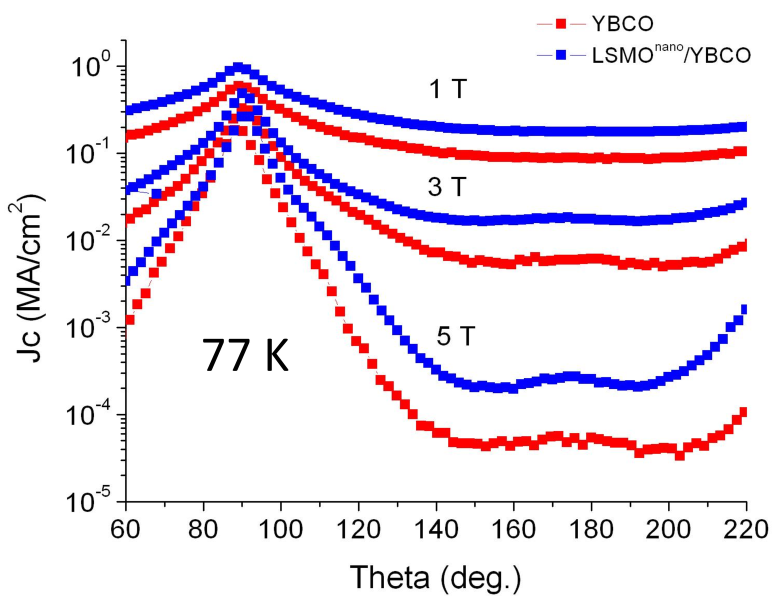


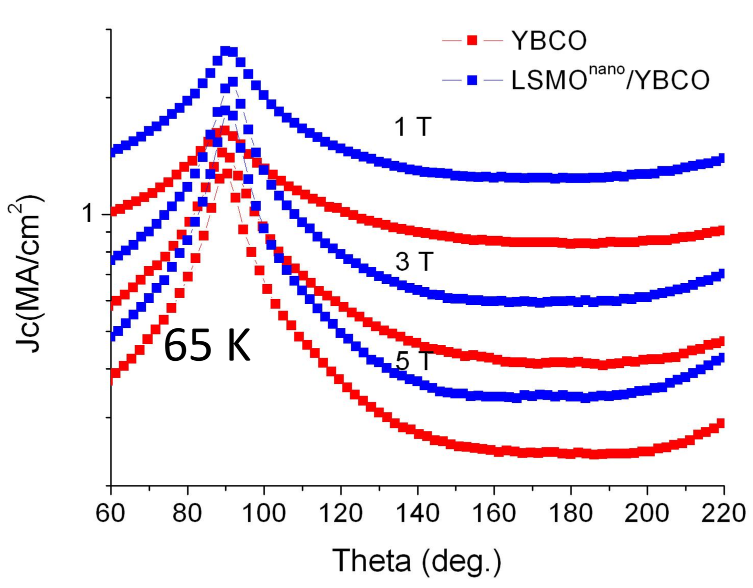




- Dew-Hughes representation of the $J_c(B)$ data for pinning population identification
- No clear indication of the presence of an additional (magnetic) pinning mechanism was observed in the $LSMO^{nano}$/YBCO film

Field angle critical current density dependence





- Improved critical current densities were observed in the case of the $LSMO^{nano}$/YBCO in all angle, temperature and field ranges;
- Similar features were observed in both samples suggesting a common pinning origin

Conclusions

- LSMO nanoparticles having a mean diameter of 25 nm and a surface density of ~ 500 μm^{-2} were obtained by the PAD method;
- improved transport properties in of the YBCO film deposited on the LSMO decorated MgO (001) substrate in all temperature and field ranges;
- no clear indication of an additional (magnetic) pinning mechanism $LSMO^{nano}$ /YBCO;
- influence of the grain boundaries on the pinning properties of the $LSMO^{nano}$ /YBCO structure is assumed to be responsible for the improved superconducting transport characteristics;

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